NEW PRODUCT

Exploring the New 3500 Hydro Monitor

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Hydroelectric turbines are subject to unique forces and operating conditions, typically operate at low operating speeds (below 100 rpm), and generally incorporate vertical shaft arrangements. For these reasons, they exhibit unique vibration characteristics and require specialized filtering for monitoring the various relevant machinery condition parameters. Our new 3500/46M Hydro Monitor Module is one of the newest members of the 3500 Series, and has been specifically designed for these requirements.

Some of the vibration behaviors typical of hydroelectric turbines are caused by Rough Load Zone, Shear Pin failure, faults with or debris in wicket gates, stator faults, and various sources of unbalance. The 3500/46M provides alarm indications for these and other vibration conditions with the low frequency sensitivity necessary to effectively monitor hydroelectric turbines. Inherent with these low speed turbines are longer response times and larger vibration levels; therefore, the design of the 3500/46M extends these options beyond those of our other radial vibration monitors. The 3500/46M Hydro Monitor incorporates eight measurement types, per monitor channel, for reliable protection. These measurements are:

- Direct
- NOT 1X
- 1X amplitude
- nX amplitude
- Gap
- Composite
- 1X phase
- nX phase

We will describe each measurement type and explain how they relate to hydroelectric turbine monitoring.

3500/46M monitor is specifically designed for hydroelectric generators and turbines.

Direct

This is an overall vibration measurement; it contains all frequencies within a specified filter window. For the 3500/46M, the window is from 0.1 Hz to 500 Hz. While this window may seem wide for a hydroturbine, it is designed to capture frequencies extending from subsynchronous (often occurring during operating conditions called “Rough Load Zone”) up to supersynchronous (generally related to turbine blade passage). Vibrations due to Rough Load Zone operation occur at subsynchronous frequencies as low as 0.25 times the rotative speed of the turbine. The allowed minimum rotor speed, for this monitor, is 25 rpm. At 25 rpm, Rough Load Zone vibration frequencies will be included in the Direct measurement. At the upper end, the allowed maximum rotor speed is 1500 rpm. Supersynchronous frequencies may occur at many times the rotation speed. These high-end frequencies may be caused by clogged wicket gates or Shear Pin failure. For this reason, the Direct measurement contains frequencies up to 20X greater than the maximum rotor speed. The Direct measurement is a combination of all frequencies inside the filter window. The measurement is displayed as peak-to-peak amplitude.

Gap

This is a dc measurement; it indicates the distance (or Gap) between the probe tip and the shaft. Gap is determined by filtering out the dynamic signal (ac portion of the waveform) and looking only at the dc portion of the waveform. Because the rotor speed is very low for hydroturbines, the low-pass filter is set at 0.05 Hz. In addition, the Gap reading may be configured for volts dc or with a zero-position for toward and away movement. When configured in the zero-position mode, the monitor will produce a Gap-percent-change value. The Gap-percent-change is used to calculate the Composite measurement, which is for the purpose of detecting Shear Pin failures and other problems related to water flow through the wicket gates.

NOT 1X

This is an overall vibration measurement with the 1X component attenuated; in other words, all vibration components *except* those occurring at shaft rotative speed. This measurement uses a tracking filter with a Q* of 18 to attenuate the 1X component. With the 1X signal attenuated, which is usually the predominant component in hydroturbines, the remaining signal will be the subsynchronous vibration due to Rough Load Zone conditions or supersynchronous vibration. Therefore, the NOT 1X is the primary measurement used for Rough Load Zone vibration. This allows the operator to alarm on Rough Load Zone vibration, if required. In addition to alarm setpoints, an option has been implemented on the NOT 1X measurement for enabling or disabling Trip Multiply. When the NOT 1X Trip Multiply is disabled, and an alarm level is exceeded, the alarm relay may be used to actuate the rack Trip Multiply feature and cause all other alarms to be multiplied except the NOT 1X. This may be used to prevent other alarming while the hydroturbine passes through the Rough Load Zone. Another feature specific to the 3500/46M is the available options for alarm time delays. The alarm delays may be set from 1 to 400 seconds. This is especially useful while waiting for the hydroturbine to pass through the Rough Load Zone.

1X Amplitude and Phase

This is a measurement of the vibration that is synchronous with rotor speed (1X). A tracking filter with a Q of 18 is used to attenuate all other components. This measurement is valid at speeds between 25 rpm and 1500 rpm, which is applicable for most hydroturbines. This measurement is used to determine acceptance regions and provide data for detecting forced vibrations that may be introduced by bearing wear, unbalance, wicket gate damage, blade damage, generator faults, debris passing through the machine, and other conditions. An amplitude and/or phase change can be indicative of the above conditions.

nX Amplitude and Phase

This is a measurement of the vibration that is an integer multiple (nX) of the rotor speed. A tracking filter with a Q of 18 is used to attenuate all other components. “n” may be configured to an integer value selected by the operator. Typically, this is used to detect guide vane blockage or Shear Pin failure, but may be used for detection of other faults that will cause supersynchronous vibrations. One major cause of supersynchronous vibration is reduced water flow through a wicket gate. This will cause a low-pressure region, and each time a blade or bucket passes through it, an impulse is felt on the rotor causing a supersynchronous vibration equal to the number of blades. Setting “n” to equal the number of blades will cause the nX amplitude and phase to be detected.

Composite

The composite measurement combines the Gap and nX amplitude to provide a means for detecting and alarming on Shear Pin failure or other types of conditions that change the flow of water through a wicket gate. In addition to the nX vibration caused by the newly created low-pressure region, the shaft position will also move toward that low-pressure area. The Gap measurement will detect the change in shaft position. Composite is simply the nX amplitude multiplied by the percent-change in Gap. These two major indicators of Shear Pin failure are combined into one convenient measurement to provide extra machine protection.

Summary

This brief introduction has highlighted and explained the new 3500/46M measurement types for hydroturbine applications. When the 3500/46M is combined with thrust position measurements, wicket gate position measurements, process conditions such as flow, temperatures of bearings and generator windings, and our new HydroScan® series of measurements (Editor’s Note: see *Hydroelectric Solutions Expanded with Acquisition of HydroScan® Technology*, Second Quarter 2000 ORBIT, Vol. 21 No. 2, page 32), Bently Nevada offers total solutions for protecting and managing hydroelectric turbines and generators. For more information, contact your local Bently Nevada sales or service professional.

**Q is a filter’s center frequency divided by its bandwidth, and is a measure of how narrowly the filter can pass the desired frequency and attenuate all other frequencies – even those very close to the center frequency.*